DOCUMENT RESUME

ED 160 286 RC 010 783

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TITLE Plant Galls and Ecological Concepts: A Multidisciplinary Outdoor Education Teaching Resource Packet.
INSTITUTION Cortland-Madison Board of Cooperative Educational Services, Cortland, N.Y.
PUB DATE Dec 77
NOTE 37p.; Best copy available
AVAILABLE FROM Cortland B.O.C.E.S. Outdoor-Environmental Ed. Program, McEvoy Educational Center, Cortland, New York 13045 ($1.00)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS *Activities; *Botany; Concept Formation; Definitions; *Ecology; Elementary Secondary Education; Illustrations; Interdisciplinary Approach; Language Arts; *Lesson Plans; *Outdoor Education; Plant Identification; *Resource Materials; Sciences; Social Studies

ABSTRACT

Designed for adaptation in primary through high school classes, the lessons in this resource packet use the development of plant galls (plant growths caused by irritation of the plant tissue) as a focus for outdoor education studies and activities. Emphasis is on science and ecology, though other disciplines are represented. Illustrations and narratives present the following: a definitive statement on galls (historical considerations, function, importance, etc.); an illustrated narrative discussing the different types of galls; a narrative on ecological relationships (addresses the following concepts as demonstrated by study of galls: ecosystems operate as a whole unit and all things are interrelated, interconnected and interact with other living and non-living things; all living things need air, sunlight, water, and nutrients; all living things need and use energy, and energy is constantly produced and lost through organism maintenance and trophic exchanges; movement of matter provides connections and exchanges of materials between ecosystems); pre-trip lesson ideas for science, language arts, and social studies; the lesson plan for studying galls (presented in outline form, this includes objectives, what is a gall, cutting a gall open, discussing the benefits of a gall for man, gall maker, etc.); interrelatedness and interdependence as illustrated by the gall story; energy flow concepts and the gall story, etc.; post-trip follow-up suggestions; gall crafts (mobiles, jewelry, etc.); cross-word puzzle; a fact sheet; and a glossary. (JC)

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PLANT GALLS AND ECOLOGICAL CONCEPTS: a Multidisciplinary Outdoor Education Teaching Resource Packet

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INTRODUCTION

One of nature's most fascinating stories can be discovered in the world of plant galls. These growths, caused by irritation of the plant tissue, range from the beautiful to the grotesque, the microscopic to the obvious, the harmful to the beneficial. The story of these galls is not only extremely interesting, but it provides a valuable lesson in ecology, as students can discover and study the many relationships which exist in the gall story.

This packet of resource materials, a lesson plan, and pre and post trip ideas and suggestions constitute a bit of departure from our usual multi-disciplinary resource packets. First, it is heavily science- and ecology-oriented, although there are plenty of other curriculum areas represented inside. Secondly, an attempt is being made to provide a resource which has significance for teachers and students of all levels, from primary to high school. Obviously this cannot be done without including some activities which will be inappropriate for specific age levels, but it is hoped that teachers will take relevant materials and apply them to their specific needs.

Through utilizing real world experiences in the outdoors, and capitalizing on these experiences when back in the classroom, teachers can immeasurably enhance the learning process. Galls provide a unique focus for an outdoor education experience, which can encompass all curriculum areas. Hopefully, through using the resources compiled in this packet, more teachers will take more classes to discover more about the real world.

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PLANT GALLS

A gall is an abnormal growth of plant tissue that is produced by a stimulus other than the plant itself. This stimulus may be due to: a mechanical irritation, such as 2 limbs rubbing together; a fungus growth, like the black knot gall; or due to an animal, either a nematode, a mite, or an insect. The gall is actually an association between the plant and another organism.

Historical Considerations

The formation of galls may have been the first insect habit that was observed by man. Theophrastus (372-286 B.C.) refers to the medical and curative properties of galls. Pliny (60 A.D.) made reference to their habits and their rapid growth. Galls have been around for a long time.

It is believed that galls originated through the fungus-feeding or predacious habits of certain insects. Galls probably evolved through the leaf rolling habit that many insects use to secure their safety and protection. The leaf responds to the insect leaf-roller by a development of cells and a thickening about the injury. Often it is difficult to determine where the boring ends and the gall making begins in evolutionary development.

What Is A Gall?

The abnormality, or the gall formation, may occur on any part of the plant: buds, leaves, flowers, twigs, under bark, or in the roots. In fact, many people are more familiar with the galls than they are with the insects that produce them. Galls are abundant, colorful, and often grotesque. It is the tendency of the plant to react to the injury in such a way that it results in a callousing, which is a gall formation.

The gall insect lays its eggs upon the host. Either the insect actually inserts the egg into the tissue of the plant with its ovipositor; or it lays its egg on the surface of the plant, and when the egg hatches the larvae will bore into the tissue. The larva finds its way to the cambium layer or to some portion of the plant that is capable of growth. There is usually no distortion until the egg hatches, and then the gall grows with the insect.

Function Of Galls

The gall has the function of being a dwelling place for the insect during the larval and often the pupal periods. The larval period is a phase of feeding and growing. The pupal period is an adaptive phase of reconstruction and transformation during which the insect is helpless. The gall is thus serving as a shelter, and as a source of food for the larva and the pupa.

The inner walls of the galls are often richer in protein than the portion of the plant upon which it grows. This aids the gall insect in giving it a better diet than it could have obtained without the gall formation.

The gall formation also protects the insect from desiccation, or drying up.

Guest wasps, or inquilines, utilize empty galls for the protection of their young. A wasp (Ancistrocerus Tigris) lays its eggs in an empty goldenrod ball gall cavity. It then provides the eggs with an anesthetized caterpillar, and seals up the old exit hole with a plug of mud. In this example the wasp is not harmful to the gall maker, nor to the plant. The gall's function for the wasp is one of shelter and protection.

Vacant galls are also known to be the breeding grounds of various fungi.

Importance of Galls and Their Uses

The chief product obtained from galls is tannic acid. This substance is used in the treatment and preservation of hides. The staghorn sumac gall con-

Importance of Galls and Their Uses (cont.)

tains a large amount of tannic acid. The sumac gall is the gall used in tanning hides in the United States. The tannic acid combines with the geletine, which is the chief element in hides, to tan them into leather.

The hide is soaked in a solution of ashes and water to remove the hair and bits of flesh. Next the hide was worked with the hands and rubbed with sticks to make it soft and pliable. This took about three months.

The hides were then placed in a tan-pot, alternated with ground-up galls. The pit was filled with water, and the tanning process was allowed to continue for several months. A final rubbing with bear-oil or tallow made the hides soft and pliable.

Nicotine tannic is derived from tannic acid. This chemical was developed for use as an insecticide against the codling moth and other insects.

Galls have been used the world over as a dye source. The "mad apple" gall of Asia Minor gives us Turkey red. Natives of East Africa use galls as a source of dye for tatooing. The Alleppo gall was used to dye hair black.

The Alleppo gall is caused by a gall wasp (Cynips gallaetinctoriae) on oaks in Europe and West Asia. It is a chief source of ingredients for inks. In fact, the Alleppo gall is specified in formulas for ink used by the U.S. Treasury.

Many superstitions have surrounded galls. It was believed that: if a gall contained a maggot, famines were to come; if it contained a fly, war would result; and if it contained a spider, pestilence resulted.

The Alleppo gall was used for even another use, that of a vegetable astringent. In the 18th century galls were used in France to control fevers.

Most of us find it difficult to relish the thought of eating galls, especially when we think of the creepy crawlies living inside. Some cultures are not quite as repulsed by the idea. In the Near East a gall of the sage is aromatic and fla-

Importance of Galls and Their Uses (cont.)

vorful, and said to be delicious with honey and sugar. The gall on Creeping Charley (Glechoma hederacae) is used as a food in France. It is said to have the sweet odor of the host plant. The "black oak wheat" gall is used as a food source for cattle, sheep, chickens, and turkeys in Missouri and Arkansas. It resembles wheat and is readily eaten by the animals.

Many galls produce honeydew, which is a substance collected by bees. It greatly helps in honey production. Many times the gall forming insects aid in the cross pollination of flowers.

As an agricultural byproduct, root nodules are of great benefit to farmers. They are a type of gall that forms on the roots of legumes. These root nodules form a bacteria, rhizobium, that has the ability of fixing nitrogen. Some of the nitrogen is absorbed by the legume, but large amounts remain fixed and usable in the galls. When the nodules are detached and decay, as much as 200 lb. per acre of nitrogen is left in the soil by the galls.

Problems Caused By Galls

Many different galls can cause economic problems for man, especially in the raising of crops. For example, corn smut is a grotesque fungal growth that ruins corn for human or animal consumption. The Hessian fly has caused millions of dollars of damage to our wheat crops. On an individual point of view, many fruit trees and even ornamental plants can be damaged by galls.

The plant itself often suffers from the gall infestation. Solitary trees are more likely to be infested with galls than those that exist in woodland areas. The plant often suffers a loss of sustenance. There is generally a deviation in the direction of growth and often the gall disturbs the normal sap flow. The gall development may even cause a premature decay in the plant. In summary, the growth of the non-essential gall parts occur at the cost of the essential parts of the plant.

Adaptations and Reactions to Galls

Adaptations are varied in the plant. The plant may form additional tannin that is unpalatable and discourages feeding by other species. Hair and spines may develop on the surface of the gall. The wall of the gall is harder and thicker than the plant itself. The portion of the plant attacked is frequently modified in color and shape to resemble flowers, fruits, seeds, or fungi.

Insects also exhibit various adaptations to development within a gall. The larvae and nymphs show a reduction in the size and often number of antennae and legs. The bodies of gall inhabiting species elongate. The salivary glands may be more developed in gall-forming generations of certain aphids. The gall midges share greatly mixed habits of scavengers, fungus feeders, predators, and leaf miners.

The alternation of generations is common among the gall wasps and aphids. This habit occurs in insects other than the gall makers, but is well adapted to the gall making habit. In normal development, the species reproduces agamically, only females, all summerlong; and sexes are produced only at the approach of fall to mate and lay winter eggs. The gall-makers reverse this and produce agamic generations as the overwintering form and the sexual generation is the summer form. In the alternation of generations the gall-making habit leads to a special method of hibernation that occurs in no other gall-making species.

TYPES OF GALLS

Chances are that everyone has seen the curious plant growths known as galls. We will take a closer look at a few of the galls that you may expect to find in New York. This is a minute sampling of all the galls that exist, but we hope we will give enough information so that you will be able to find a few of these galls for a closer investigation. The scientific name of the gall makers are given.

Goldenrod Ball Gall (Eurosta solidaginis)

Wherever the Canada goldenrod grows, you are likely to find the goldenrod ball gall. This gall is formed by the peacock fly, a pretty insect with pictured wings. New galls first appear by June and by fall they are almost the size of hickory nuts, but have the texture of the stem.

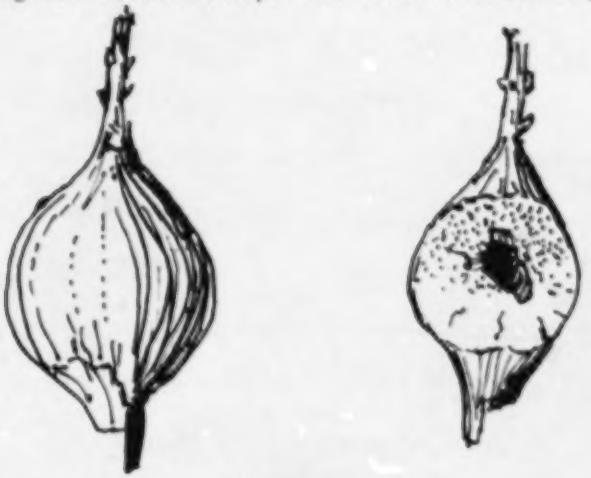
The insects remain in the galls all winter. Some transform into pupae, but most remain as larvae. Before the larva pupates, it uses a pair of mouth hooks to excavate a tunnel in preparation for its exit. It does not tunnel past the epidermis of the stem, leaving this thin plant membrane intact. When it becomes an adult fly, it inflates a special balloon-like structure called the ptilinum. This ptilinum is inflated until it pushes away the epidermal cap of the gall. The fly crawls down the tunnel and out of the gall. The ptilinum is deflated and never used again.

If you open a gall and find a prematurely formed pupal case, but no tunnel was formed; you probably have discovered the gall infested by a certain gall wasp that is the chief parasite of the golden rod ball maker.

The mordellid beetle and the downy woodpecker are the main predators of the goldenrod ball gall maker. Often you will find a gall that has been pecked open by the downy woodpecker. Surely that morsel of protein has been savored on a cold winter's day !

The goldenrod ball gall fly has to hope, if he is capable of hoping, that the snow will bend the goldenrod stalk down so that they are covered with snow, thus

protecting him from the downy woodpecker. Unfortunately for the little gall maker, he then has hungry mice to contend with. Nature has its many checks and balances. (See section on Ecological Relationships for more information)



Goldenrod Bunch Gall (cecidomyia solidaginis)

This gall is also found on the Canada goldenrod. It is formed by a tiny midge. The adults emerge early in the fall, but little is known about their winter habits. The midge lays its eggs in June and the larvae are present in July. The midge deposits its eggs on the growing tip since the ovipositor is too weak to penetrate the plants' tissues.

The gall develops when the larva secretes chemical substances that induce the plants' reaction. The larvae lacks jaws. It has a hard "breastbone" that rasps away at the plant tissue and stimulates the flow of juices. The larvae then absorbs these juices through its skin.

This gall is in the form of a stem that has been prevented from elongating. It has the appearance of leaves being crowded together into a "bunch".

Goldenrod Elliptical Gall (Gnorimoschema gallaesolidaginis)

The Canada goldenrod is once again the victim of yet another gall maker. This gall is characterized by a very spotty distribution; many in one area, few in another. It is a gall caused by a moth.

The adult emerges in the fall, mates, lays its eggs, and then dies. The eggs hatch the following spring and the caterpillars migrate to the goldenrods. They bore into the buds and tunnel down the stem. The gall then develops around the caterpillar.

An interesting aspect of this goldenrod elliptical gall is that the exit plug and hole are tapered like the "bung" in a beer barrel. The plug is translucent so that it can guide the moth out by the light.

Willow Pine Cone Gall (cecidomyia strobiloides)

The willow pine cone gall maker is not particular to its host, as long as it is a native willow species of the United States. It is a gall formed by a little gall gnat. The gnat deposits eggs in the spring on the opening buds. The maggots hatch and their secretions cause the "pine cone" swellings.

In the autumn the gall and a section of the stem just below it die. As the dead gall shrinks, the scales spread apart. Parasites and predators now are able to gain entrance. This dead pine cone gall is a winter haven for midges, aphids, plant bugs, thrips, midges, spiders, flea beetles, and centipedes. See if you can add more to this list.

Oak Apple Gall (Amphibolips confluenta on black oak, Amphibolips inanis on red oak)

This gall is host specific. Generally, if you can identify the host, then you can identify the gall maker. This gall is actually a leaf deformation and is caused by a wasp.

The female wasp inserts her ovipositor into the leaf stem and lays an egg. She also injects an irritant that initiates the gall formation. Typical oak apples are round, one to two inches in diameter, and with a spongy inside and a hard central core. These galls can usually be seen in May or June.

Raspberry Knot Gall (Diastrophus turgidus)

The raspberry knot gall forms on the canes of raspberries. A similar gall is also found on blackberry canes. It is caused by a wasp, and is a very good collecting gall in the summer. Just put it in a jar with cheesecloth and many little wasps will emerge.

Black Knot Gall (Plowrightia morbosa)

The black knot gall is a very grotesque looking gall that is caused by a fungus. Most fungi reproduce by spore. When the spore lands on a break in the twig, the black knot gall begins to form. The fungal threads penetrate the vascular system of the host and eventually will kill it. Wild cherry is the frequent victim, but it also attacks domestic fruit trees.

Maple Spindle Gall (Vasates aceris-cremeno)

The maple spindle gall is caused by a tiny mite. It has only two pairs of legs and the abdomen is long and striated. This mite attacks soft, sugar, and white bark maples. The spindle galls are formed on the upper surface of the leaves. During certain seasons, the galls are common on hard maples growing in woodlands, forests, and along streets and highways.

The galls are about 1/5" long and as thick through the middle as the lead of a pencil. The galls are formed late in the season, so the injury to the tree is not serious since it is only temporary (the leaves were going to fall anyway). The main damage is of an aesthetic nature in that the foliage is distorted and drops prematurely, but little control is necessary.

ECOLOGICAL RELATIONSHIPS

What is Ecology? What makes it so unique? Simply, Ecology is the study of RELATIONSHIPS, between living things, and between living and nonliving things. Disciplines such as Biology and Social Studies often deal with individual things and concepts, without taking the total relationship picture into consideration. Ecology deals with all the factors affecting an organism or thing, and considers these relationships in total. Although often it is difficult or impossible to determine all the factors affecting relationships, even beginning to understand these complex workings brings a better appreciation of the value of these relationships to the natural world and mankind. Galls, in providing an easy-to-use illustration of many of these relationships and concepts, can enhance the appreciation and understanding of Ecology.

This section is not designed to be a primer on ecological concepts. There are many fine books and resources on this subject. This section will list each concept and briefly discuss how galls can be used to illustrate them.

A lesson on galls lends itself beautifully as an illustrator of ecological concepts. In fact, the ease with which galls can be used to illustrate such concepts as interrelatedness, nutrient cycling, energy flow, and predator/prey relationships may be the greatest value of discussing galls. Understanding ecological relationships is of paramount importance today and will be more so in the future as man is forced to live within the means of the natural world, not apart from it. By using galls as an illustration, abstract concepts can become meaningful and a better understanding of ecological relationships can emerge.

I. Concept: Ecosystems operate as a whole unit. All things are interrelated, interconnected and interact with other living and non-living things.
Galls can illustrate this easily through considering two things: What are the factors affecting galls and their host plants; and how galls affect other things.

A. Factors affecting galls and gall makers:
   1. Plant (Host Organism)
      a. Use of sunlight, water, soils and air to produce food (as an autotroph) and energy, extent to which may affect gall formation and survival.
   2. Weather
      a. Temperatures can be critical at times
      b. Heavy snows can protect some galls from predation
      c. Any weather that affects host plant affects galls
   3. Predation/Parasitism
      a. Predators of galls include woodpeckers, other insects such as wasps; and mice
      b. Fungi or bacteria
   4. Man
      a. Agricultural practices
   5. Available food and energy
      a. Confusion of generations occurs through lack of food
   6. Strength of gall maker
   7. Mobility of gall maker

I. Concept: (cont.)

B. Effects of galls on:
   1. Uses by man
      a. Dyes
      b. Tannic acid
      c. Food
   2. Plants
      a. Physical deformities
      b. Decreased lumber value/trees
   3. Insects
      a. Secondary use as home after gall maker is out
      b. Guest insects using galls after formation
   4. Relationship:
      a. Some galls (caused by insects) are examples of commensalistic relationships, meaning that the insect derives a benefit of food and shelter from the plant, and the plant is not considered to be harmed. Goldenrod galls are good illustrations.
      b. Mutualistic relationships, where both plant and gall maker derive benefits, are illustrated by the bacteria-caused galls formed on legume roots, which fixes nitrogen in the soil.
      c. Parasitic relationships are often observed in galls formed by fungi, such as the Black Knot Gall. These relationships exist where one organism derives a benefit to the disadvantage of another organism.

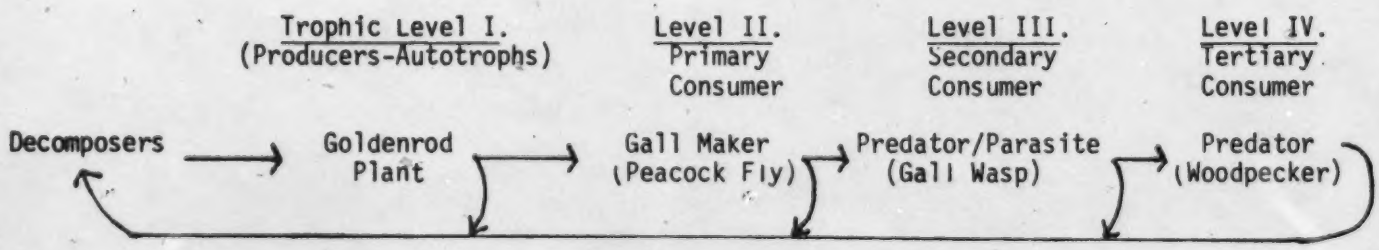
II. Concept: All living things need air, sunlight, water, nutrients.

A. Gall maker obtains nutrients from the host plant, which, in turn, produces this food through synthesizing light, water, air, and soil minerals (photosynthesis). Organisms which use light to produce food themselves are called photoautotrophs. The gall maker is usually considered to be heterotrophic, i.e., consuming nutrients produced by sources other than itself. Thus, indirectly, it is also dependent on air, sunlight, water and soil for food.

Predators and/or parasites of gall makers obtain nutrients from eating the gall makers. All of the above organisms eventually die, and return their nutrients to the soil or more usable forms through decomposition. This process is speeded by decomposing organisms, which also work on waste materials.

It is important to realize that, unlike energy, nutrients are not released and lost. They are constantly being cycled and recycled through the various trophic levels. A diagram or flow chart illustrating this may be helpful.

NUTRIENT FLOW CYCLE

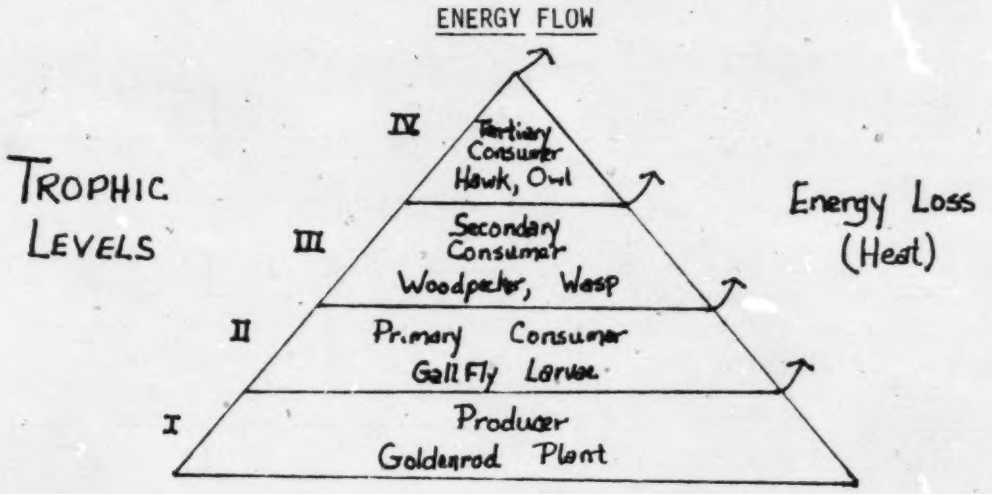


Decomposers release nutrients in usable forms. All living organisms, when wastes are produced, or death occurs, will undergo decomposition, releasing these nutrients to be cycled once again. Nutrients can escape from ecosystems only through Movement of Matter (concept IV.).

III. Concepts: All living things need and use energy, and energy is constantly produced and lost through organism maintenance and trophic exchanges.

Energy is produced and stored by plants. Consumers utilize this energy as food, then storing it in fats or giving it off in the form of heat. Energy is lost each time a trophic level exchange occurs (second law of thermodynamics). It is important to understand the energy flow concept, for it determines many things in the natural world.

To illustrate the energy flow concept with galls, a pyramid can be utilized.



Energy flow is similar to nutrient cycling, except that it is a one-way process, and energy must constantly be produced by plants. No recycling occurs with energy. Energy is lost through organism maintenance (digestion, respiration, heat, reproduction, etc.) and in transformation from one trophic level to another. Available energy determines biomass (total mass of living organisms) and the arrangement and distribution of organisms.

IV. Concept: Movement of matter provides connections and exchanges of materials between ecosystems.

A. Matter can be moved through:
   1. Meteorological means, as in wind and rain;
   2. Geological means, as in water and gravity;
   3. Biological means, through animal power.

IV. Concept (cont.)

This movement has significance, for it provides for the mobility of both energy and nutrients, which may be produced or utilized in one ecosystem and consumed in another. This makes ecology much more complex, but it does account for lost nutrients and unaccounted for energy.

Gall formation can illustrate this concept; by determining what caused the gall, how it got there, and how or whether or not the gall maker remained. For example, the Black Knot Gall is formed by fungal spores, transported by the wind, or possibly through animal or water contact. The Goldenrod Ball and Eliptical Galls are formed by flying insects, whose offspring derive energy and nutrients from one system and may leave that system on maturity if conditions warrant.

In static systems, the influx and output of energy and nutrients tend to balance out, causing little change. An imbalance in movement of matter tends to cause change. The presence and mass of galls and their host plants could be indicative of change, or the status of the system.

V. Summary: One way to illustrate ecosystem concepts is to consider the gall maker, its host plant, the plant's needs, predators, and parasites of the gall contents, and predators on the third trophic level. In other words, consider the energy and nutrient inputs and derivations, and all trophic levels and their relationships concerning galls.

Then remove one of these components, and discuss the effects of the removal on the rest of the gall system. Do this for each component. This should promote an understanding and appreciation of the concept of interrelatedness, and should strengthen the comprehension of each of these important ecological concepts.

Pre-Trip

Pre-Trip lesson ideas are designed to insure that students will be able to understand the concepts necessary to successfully complete that portion of the actual lesson which is to be done. As with the lesson plan itself, these pre-trip activities should be adapted to the specific needs of the students. These pre-trip suggestions should be viewed as a nucleus of activities, and pre-trip preparation does not have to be limited to these suggestions alone. The pre-paration activities are listed in curriculum areas for easier implementation.

Science

1. Discuss the stages of insect development.
2. Discuss the three basic needs of all wildlife (food, water, shelter).
3. List the four needs of all life (water, air, sunlight, soil).
4. What is function of a predator?
5. What is a parasite?
6. Discuss ecology and the importance of its concepts in today's world.
7. Discuss the trophic level concept, and producer-consumer relationships.
8. How are galls formed? Why?
9. Discuss energy flow concepts.
10. Discuss nutrient cycling.

Language Arts

1. Define the following terms:
   a. Gall
   b. Predator
   c. Parasite
   d. Habitat
   e. Metamorphosis
   f. Hibernation
2. Review the glossary for meaning of words.

Social Studies

1. Discuss ways in which plants are beneficial to man.
2. Discuss insects and their relationships with man.

LESSON PLAN

This lesson plan is a sequential progression of learning events designed to be adapted to the needs of learners from primary levels through high school. It is hoped that teachers will utilize and adapt sections of this plan to meet the needs of their individual classes. It is anticipated that this plan will contain areas that may be inappropriate for specific grade levels, but in attempting to provide viable activities for all grades this is inevitable. Please adapt this plan to meet your needs.

OBJECTIVES

1. The students will demonstrate an understanding of the types of galls, their causes and formation.
2. The students will directly experience a scientific investigation approach and hands-on learning in discovering about the outdoor world.
3. The students will demonstrate an understanding of concepts of ecology, and relationships between living and non-living things as illustrated by galls, their host plants, and their parasites and predators.

OUTLINE

I. What is a Gall?

   A. How Are Galls Formed?

   B. What Causes Galls to Form?

II. Examine Gall by Cutting Open Carefully.

   A. Find Gall Maker.

   B. Find any Parasites, or Indications.

   C. Find any Indications of Predation.

   D. Discuss Effects of Gall Formation on Plant.

OUTLINE (CONT.)

III. Discuss Benefits of Gall For

A. Man
   1. Dyes
   2. Tannic Acid
   3. Food

B. Gall Maker
   1. Food, Shelter

C. Plants

D. Other Organisms
   1. Predators
   2. Parasites

IV. Discuss Possible Harmful Effects of Gall

A. Plant Deformation

V. Discuss The Concepts of Interrelatedness and Interdependence Illustrated By The Gall Story.

A. Ecosystem as a Whole Unit.

VI. Discuss The Gall Maker. Its Host Plant And Any Related Organisms In Terms Of Their Need And Dependence On

A. Sunlight

B. Water

C. Air

D. Nutrients (Soil)

VII. Discuss And Illustrate Energy Flow Concepts Using The Characters In The Gall Story.

A. Utilize Energy Pyramid

B. Discuss Trophic Levels

C. Discuss Energy as a Selecting Factor in Nature

OUTLINE (CONT.)

VIII. Demonstrate Nutrient Cycling With The Gall Story

A. Discuss Producer/Consumer Concept

B. Discuss Nutrient Cycling

IX. Discuss Movement Of Matter

A. How Does it Affect Energy Flow and Nutrient Cycling?

B. Discuss Relationships of Gall System With Movement of Matter.

X. Summary

A. Discuss Gall System as a Whole.

B. Discuss Gall System in its Component Parts.

C. Remove one Component and Discuss Effects on the System.

D. Repeat for all Components.

Post-Trip Followup Suggestions

These ideas are designed with a two-fold purpose in mind: To provide reinforcement for concepts learned in the lesson itself: and to give an opportunity for groups of individual students to pursue an interest which might have been developed during the lesson. Again, they are suggestions which should be adapted to each class's specific needs, and teachers should not feel limited by them.

Science

1. Conduct a gall census. Count the number of different types of galls that can be found in a defined area. Determine how many of each type of gall there are in that area. Compute the percentage and frequency of occurrence for each type.
2. Conduct a comparative gall census in different ecosystem areas: i.e. fields, swamp,hardwood forest, softwood plantations, etc.. Compare frequency of occurrence for each type of gall found. Discuss the significance of the finding.
3. Discuss ecology and its major concepts. Relate these to specific instances illustrated by galls.
4. Remove the various components from the gall system and discuss the possible effects on the remaining parts.
5. Discuss the effects of the total elimination of galls on:
   a. Plants
   b. Man
   c. Parasites
   d. Predators
   e. Entire system
6. Collect samples of each type of gall. Put them in containers and observe them for any changes over a period of months.
7. List the different kinds of gall makers. Match them with the types of galls formed and the host plants.

Science (cont.)

8. Discuss how the gall is a unique adaptation which best enables the gall makers to meet their food, water and shelter needs.
9. Discuss how other insects have evolved unique adaptations in their life cycles to best meet their needs.
   a. Aquatic
   b. Earth burrowers
   c. Animal parasites
   d. Dead log insects, etc.
10. Locate and do comparative ecosystem models for different systems.
11. Discuss and illustrate the concept of interrelatedness.
12. Make models of simple energy flow and nutrient cycling systems.
13. Find examples of movement of matter as an ecological concept; and relate it to energy flow and nutrient cycling.

Language Arts

1. Do creative writings on the feelings of an insect emerging from a gall.
2. Write a poem, cinquain, or haiku which describes an aspect of some relationship found in the gall stories.
3. Research one of the components of the gall story, and give an oral report on it, its function in the ecosystem, and the effect of its removal.
4. Look for news articles on galls.

Art

1. Take photographs in which galls are central in composition.
2. Draw the different types of galls and the insects found in them.
3. Find pictures of galls and insects.
4. See the arts and crafts section for ideas for using galls in making things.

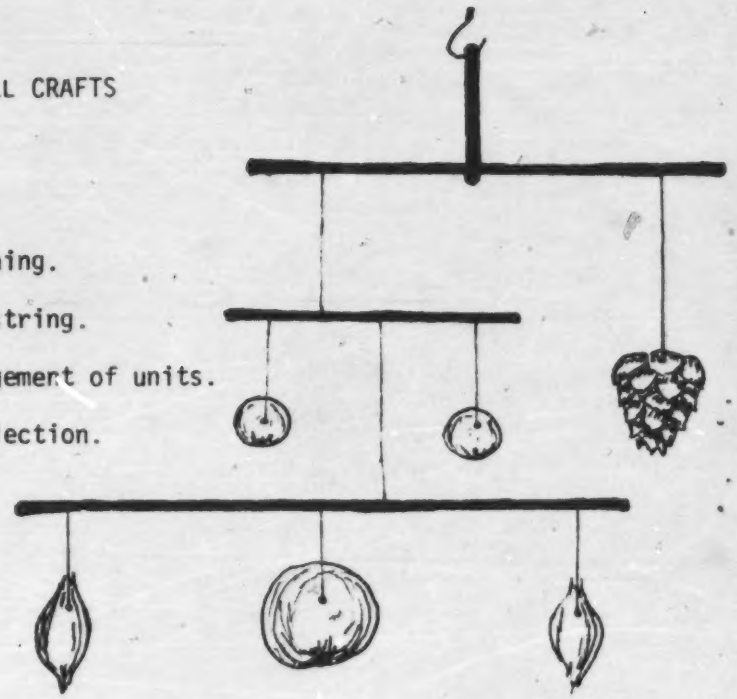
Mathematics

1. See science #1 and 2.

Social Studies

1. Discuss the possible benefits of galls to:
   a. Man
   b. Plants
   c. Animals
2. Discuss possible adverse effects.
3. Trace man's dependence and use of plants throughout history.

GALL CRAFTS



Mobiles

Moving objects hung from something.

Suspended on an inconspicuous string.

Balance is maintained by arrangement of units.

Can be a display of a gall collection.

Gall Jewelry

Galls grow in fascinating shapes and sizes; ideal objects to be made into jewelry.

Galls must be dried and sorted according to shape.

Coat of clear lacquer may be applied for a smooth and shiny coat, this also helps in preserving gall.

If necessary, make a small hole in the gall if it is to be strung: if gall is easily pierced, use a hot needle; for larger galls you may need a hand drill.

Insect Zoo of Gall Makers

Give hours of pleasure and provides opportunity to study the habits of a variety of gall makers.

Materials: insect cages made of screening, terrariums, or large-mouthes mason jars

Insect food.

Identification reference of galls and gall makers for collecting purposes.

For more information on collecting and feeding see Tip Section of packet.

Nature Gall Plaques (or arrangements under globes or in baskets)

Provides unlimited possibilities for creative activity.

Materials: Old boards, shingles, plywood, etc. for background

Household cement.

Heavy shears

Tweezers

Native materials: Galls, dried foliage, dried branches, mosses, seeds, etc.

Gall Rubbings or Crayon Prints

Using gall infested leaves, bark, flowers, etc.

Use rubbings as decoration on notepaper or cards.

Use rubbings as record of leaves and galls collected and identified.

Materials for rubbings: Cotton

Graphite or colored chalk

Newspapers

Fixative

With cotton, rub chalk on galled side of leaf.

Place paper on pad of newspapers and lay leaf on paper.

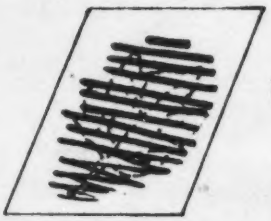
Transfer color to paper by rolling over leaf with brayer (use heavy bottle or jar).

Materials for crayon prints: Paper

Crayons

Place paper over object and rub with crayon.

Gall Rubbing



Crayon Print

Gall People and Animals

Great opportunity for creativity and imagination.

Collect galls of different shapes and sizes.

Dab together with glue.

Example: Goldenrod ball gall woodpecker

Using Burls for Firemaking set

Excellent carving project.

Work is done entirely with a pocket knife.

Fire drill fits into socket on burl and by spinning the drill, you are able to make a fire.

Facts

--- Entomologists calculate there are roughly 2,000 species of gall-making organisms in the United States.

--- 800 belong to one family of wasps (Cynipidae)

--- No type of plant is free from galls, even algae

--- Galls can develop on other galls

--- Galls may occur on any part of the plant

--- Downy woodpeckers are predators of the goldenrod ball gall larva

--- Some uses of gall insects and galls:

tanning leather
making ink
making dyes
lamp fuel
eating
ice fishing bait

--- In the goldenrod, the adult fly pushes its way out of the gall by using a balloon-like structure. This structure is found between its eyes.

--- The adult peacock fly from the goldenrod ball gall doesn't eat; sole task is reproduction.

--- Black knot galls found on cherry and plum trees will eventually kill the host tree. Most galls do not kill their host.

--- Formation of galls may have been the first insect habit observed by man

--- Alleppo galls is specified in formulas for inks used by U.S. Treasury

--- Each gallmaker produces its own distinctive gall and no other

--- Rhizobium infect roots of legume crops. The bacteria absorbs nitrogen from the air and when the gall decays, can leave as much as 200 lbs. of nitrogen per acre, for use by other crops.

--- Walls of the gall are harder and thicker than the host plant.

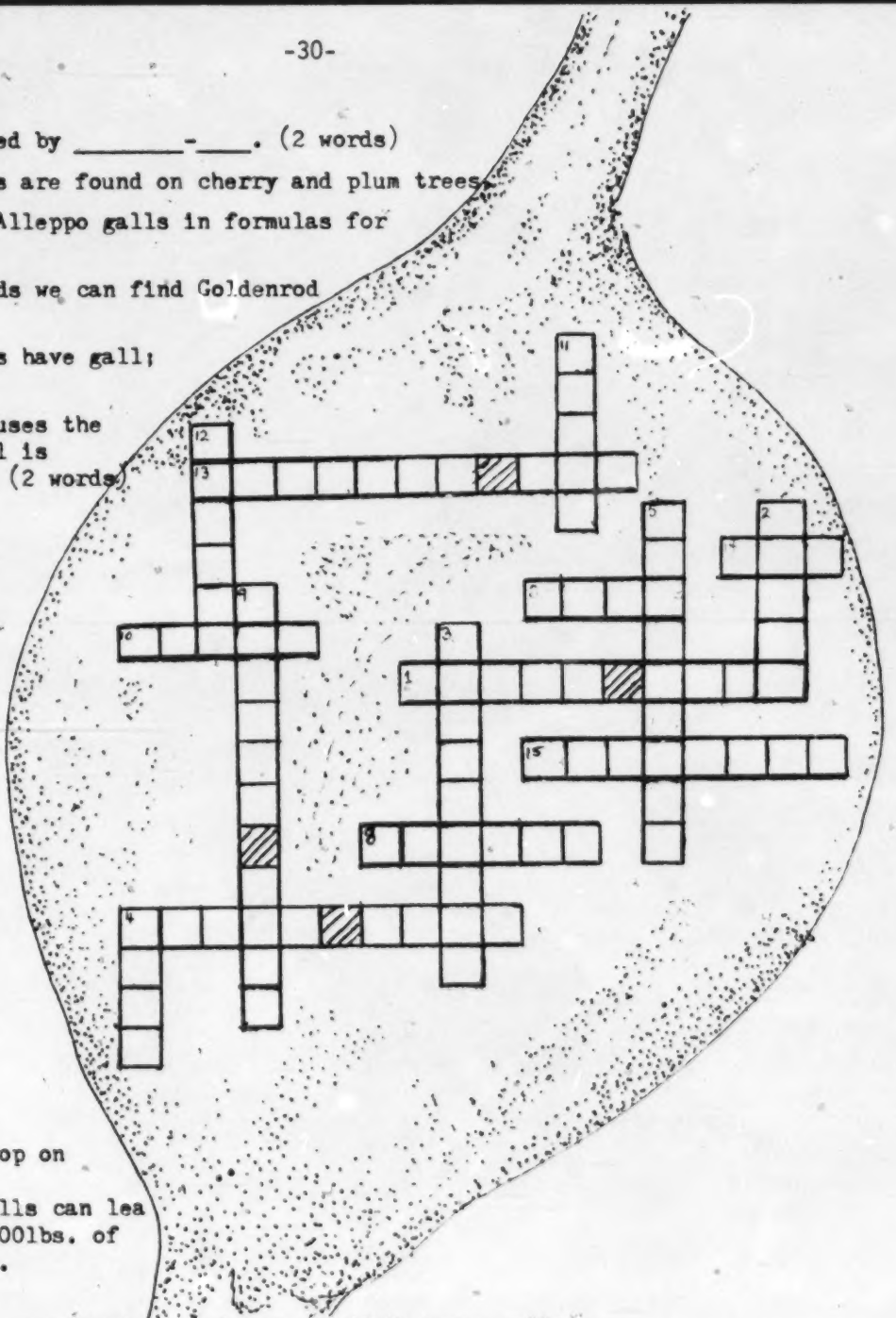
--- Portion of the plant attacked is frequently modified in color and shape to resemble flowers, fruits, seeds or fungi.

--- Bodies of gall inhabiting species elongate

--- Larvae and nymphs show reduction of antennae and legs

--- Alternate generations of gall wasps and aphids lead to special methods of hibernation

--- Salivary glands may be more developed in gall-forming insects



Across:

1. Honeydew is collected by _____-____. (2 words)
4. _____ _____ galls are found on cherry and plum trees.
6. U.S. Treasury uses Alleppo galls in formulas for _____.
8. On _____ Goldenrods we can find Goldenrod Ball Galls.
10. All Types of plants have gall; even _____.
13. The insect that causes the goldenrod ball gall is _____ _____. (2 words)
14. Galls _____develop on other galls.
15. Certain decaying galls can lea leave as much as 200lbs. of _____ per. acre.

Down:

2. 800 _____ belong to one family of insects that cause galls.
3. _____ galls are the most common galls in N.Y.S.
4. Fisherman use gall insects for _____.
5. I am a host plant. Name me, _____.
9. Sumac galls contain large amounts of _____ _____ (2 words) which is used in leather tanning.
11. Galls are found all over the _____.
12. Eggs on the Witch Hazel hatch in early _____.

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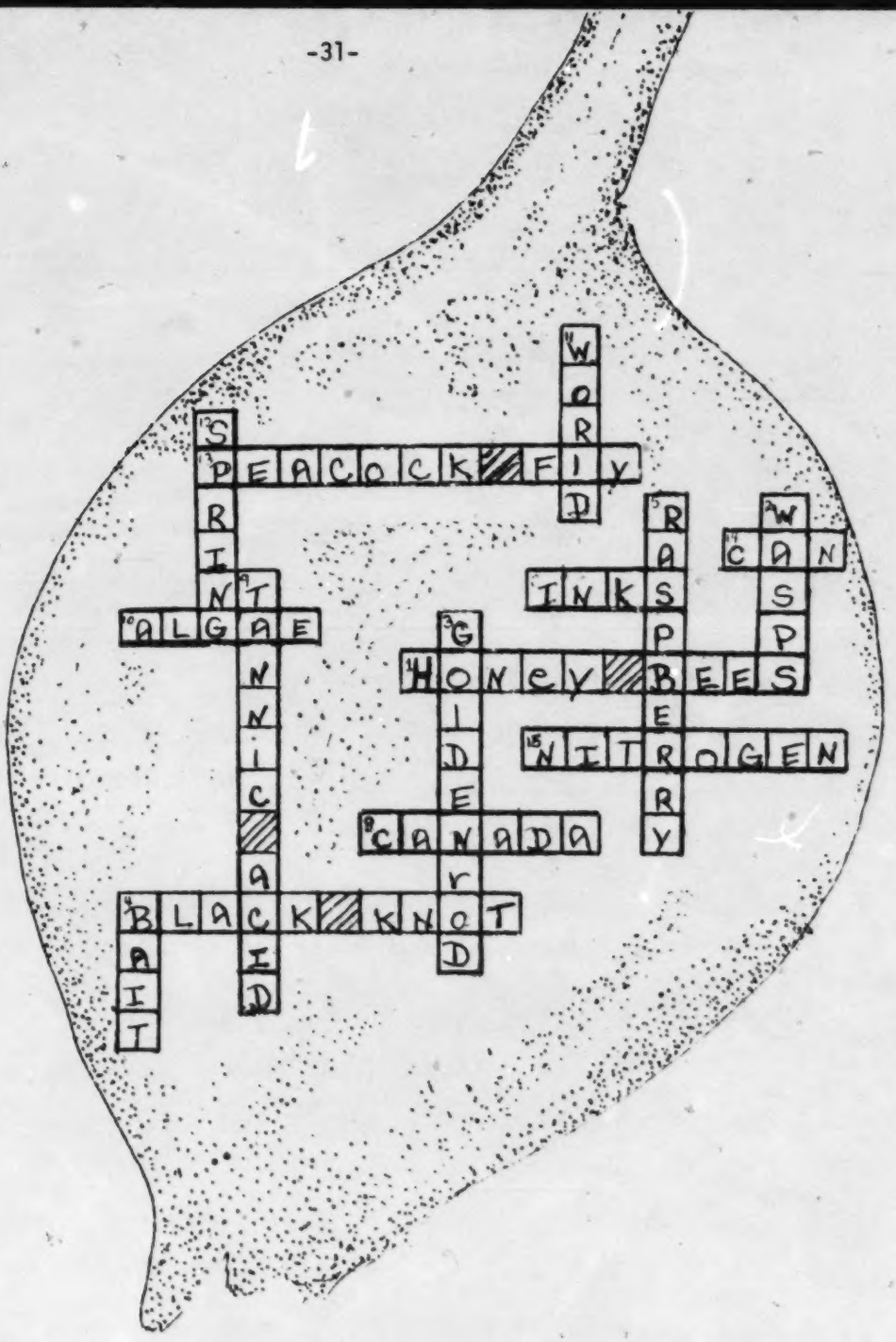
WORD
SPEACOCK FLY
RAIN
INK
RASP
CAN
WASP
ALGAE
HONEY BEES
NITROGEN
CANADA
BLACK KNOT
BAIT

Find the plants that galls are found on:

1. RRPRSBAEY _____
2. LIDW RHYREC _____
3. OKA _____
4. NELDGDOOR _____
5. TIHWC ZAELH _____
6. LWLIWO _____

To be an official Cortland County Gall Expert; you have to name 15 questions correctly.

1. _____ Goldenrod Ball Galls are found on Canada Goldenrods.
2. _____ Galls never develop on other galls.
3. _____ Willow galls are the most common galls in New York State.
4. _____ Gall insects sometimes lay their eggs on the host plant.
5. _____ Gall growth can be caused by the rubbing of two limbs.
6. _____ Galls never help man or man's plants.
7. _____ Honey Bees collect honeydew which is produced by plant galls.
8. _____ Tannic acid, which is used in leather tanning is made by sumac galls.
9. _____ Another use of galls is weaving.
10. _____ Wasps never kill other gall makers.
11. _____ The downy woodpecker penetrates the gall and eats the gall maker.
12. _____ Galls can be found on any part of the plant.
13. _____ The peacock fly causes most of the galls on the Canada Goldenrod.
14. _____ Empty galls are never used by other animals or insects.
15. _____ On the oak trees, galls are formed that are called oak apple galls.
16. _____ Willow trees are the only trees that don't have some type of gall.
17. _____ The only known galls are found in the United States.
18. _____ People at one time used galls to tell if a famine were coming.
19. _____ Females produce young within the galls of witch hazel.
20. _____ Eggs on the witch hazel hatch in late fall.

GLOSSARY

Agamic - Generation all of female sexuality.

Cambium - Layer of growing and dividing cells. Cells pushed outward form bark; those pushed in form wood, and this enables a tree to grow large. Wood cells are long; their walls thicken and harden as they mature and die.

Cecidomiidae - Gall midges.

Coleoptera - Beetles.

Cynipidae - Gall wasps.

Diptera - 2 winged flies

Haustellate - Mouthparts of insects adapted for sucking activities. Many are characterized by the presence of stylets (sword-like modifications).

Hemiptera - True bugs.

Hymenoptera- 4 winged flies.

Inquilines - Animals that live in the nest of another species.
Example: Guest wasps. They have the same power to assist in manufacture of its food as true gall maker, derives same benefit from gall as its host.

Larva - Immature stage, between egg and pupa of an insect with complete metamorphosis. Also known as grub, maggot, caterpillar, and "worm".

Lepidoptera - Moths and butterflies.

Mandibulate - Mouthparts of insects adapted to chewing activities with mandibles acting as cutting and grinding structures.

Metamorphosis - Change from one form, shape, or substance into another.

Ovipositor - Egg-laying apparatus of an insect.

Parthenogenesis - Type of reproduction in which only agamic females are produced.

Predacious - Preying upon others.

Pupa - Stage between larva and adult in insects with complete metamorphosis. Also known as chrysalis, puparium, and cocoon.

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TEACHER TIPS

Most of the galls described in this packet are best found in fall and winter. Many types of galls are particularly visible in winter, which makes this season a good one for this lesson. Be sure to dress warmly. Perhaps a combination snowshoe/gall hunt would be a good idea!

Once the galls are collected, be sure to put them in an easily observable container, one that will allow air to circulate but will prevent hatching insects from escaping. Duplicating natural conditions (i.e. temp., light) as much as possible will enhance insect development.

Don't neglect other aspects of the natural world while hunting galls. Use that teachable moment!!

Be sure to bring a jack knife to enable a closer investigation of the gall maker. For the goldenrod ball gall a lengthwise cut to the middle of the gall and prying up should leave the larva unharmed. Watch your fingers!

CREDITS

Anita Schmidt and Dan Tracy for research and development;
Anita Schmidt for art work;
Glenda Heselton for typing;
Cortland/Madison BOCES for making it possible.